The General Court of Massachusetts

INCREASING WATER SUPPLIES:

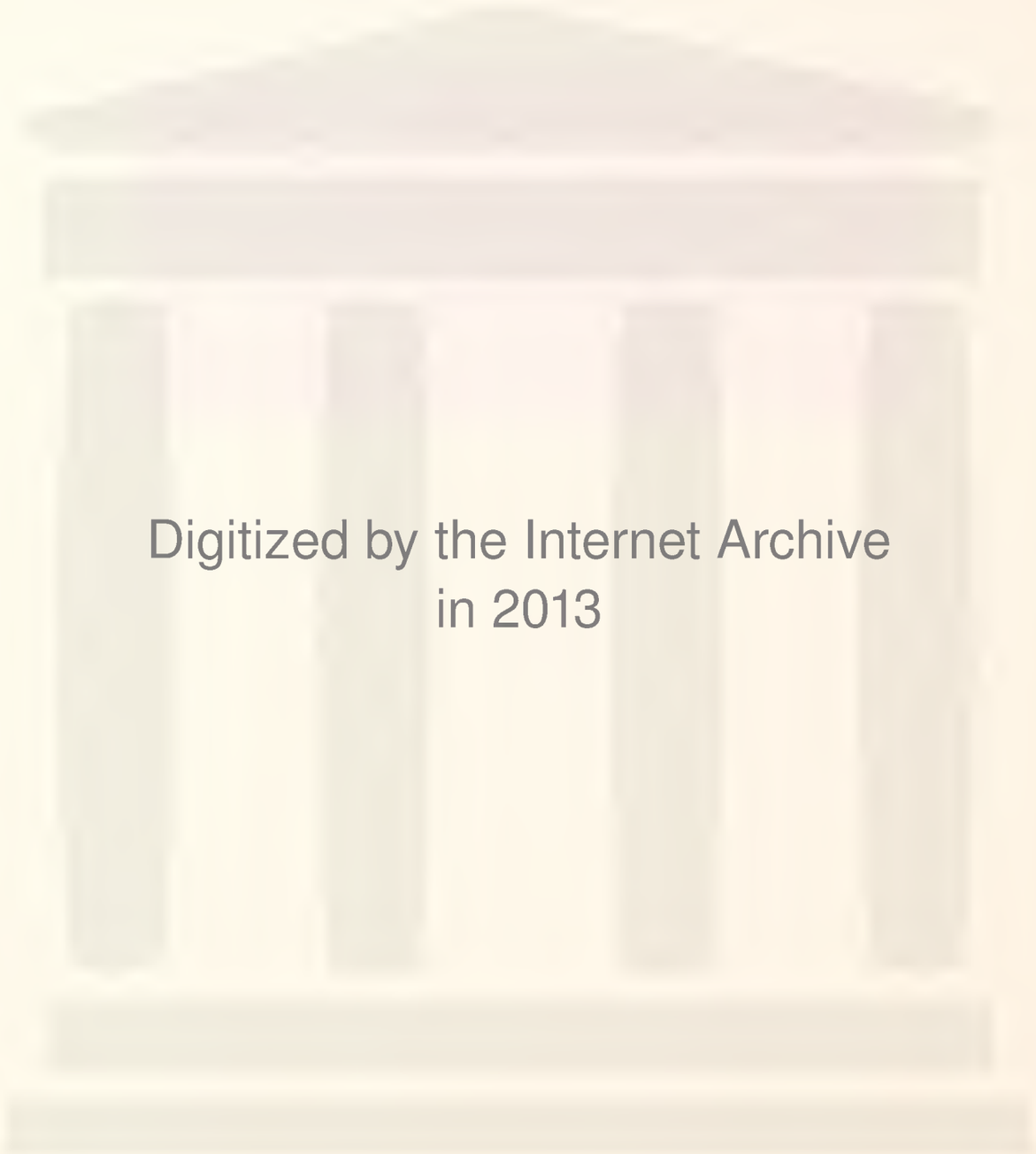
WATERSHED MANAGEMENT PROGRAM

Committee on Post Audit and Oversight

Post Audit and Oversight Bureau

INCREASING WATER SUPPLIES:

WATERSHED MANAGEMENT PROGRAM



Massachusetts House of Representatives

House Post Audit and Oversight Committee

Increasing Water Supplies:

Watershed Management Program

To: Representative Thomas W. McGee
Speaker of the House and Honorable
Members of the General Court

As Chairman of this Committee, I am pleased to present this report entitled, Increasing Water Supplies: Watershed Management Program.

This Committee believes that a contributing factor to our water supply shortages has been the uncontrolled growth of vegetation on state and municipal watershed lands with a resultant decrease in yield into our reservoir systems totalling billions of gallons annually.

This Committee recommends that both the state and municipalities should embark on a massive program of professionally supervised vegetation removal and timber harvesting on our watershed lands. Legislation is being proposed that will establish and coordinate an intensive watershed management program on both Metropolitan District Commission and Division of Forest and Park land. In addition, legislation is being proposed relative to the duties of the Bureau of Forest and Development in providing technical information and assistance to municipalities.

The result of this first in the nation undertaking will be to generate billions of gallons of additional water and millions of dollars in revenue on a sustained basis while improving wildlife habitat and recreational opportunities.

Respectfully submitted,

Kevin W. Fitzgerald

Kevin W. Fitzgerald
Chairman

SUMMARY

The Commonwealth faces continued water supply shortages. Within the next ten years, it is conceivable that the majority of the state's population could face water shortages ranging from limited to crisis proportions.

The water shortages which have occurred during the past several years may foreshadow future problems which will occur if some action is not taken now. During the past two years alone, 38 municipalities have declared water emergencies.

The Quabbin Reservoir system provides all or part of the water supply for 34 member communities accounting for 40% of the states population. For the past five years this system has exceeded its safe daily yield by an average of 20 million gallons per day. Studies predict that 24 other communities may have to rely on the Quabbin System by 1990 because of shortages or contamination of their existing water supply. These 24 communities would need an estimated 70 mgd to meet their projected needs. If this prediction holds true, every possible alternative will have to be pursued to prevent a major catastrophe in the Commonwealth.

Recognizing the seriousness of the problem, many solutions have been either proposed or already started by both the state and municipal governments. The solutions range from capital intensive programs such as the drilling of municipal wells and the purchase of new reservoir sites to low cost conservation programs such as bans on outdoor usage of water and public education programs.

HPAB believes that a partial solution to the water supply shortage which has not been given a top priority is the intensive watershed manage-

ment on state and municipal watershed lands. This position is based on the results of both scientific studies which have been completed and a limited watershed management program currently in operation.

The Cadwell Creek subwatershed study concludes that maximum water yield benefit can be derived by removing all woody vegetation from the riparian zone. A New York study of the Sacandaga River demonstrated the negative yield impact which will result from a continued policy of total forest protection such as practiced by most Massachusetts municipalities.

The Metropolitan District Commission (MDC) has operated a limited watershed management program since 1962. MDC estimates that it has achieved an additional water yield of one billion gallons annually from 24,000 acres already under a watershed management program. This program has proven to be economically sound while having the potential of increasing water yield by billions of gallons annually over the next twenty years.

At the present time, intensive watershed management in the form of timber harvesting and vegetation control is not being practiced on 85% of the municipally owned watershed land in the state. If watershed management programs were in place there is a potential of increasing water yield by billions of gallons annually while generating revenue through the harvesting of marketable timber. While this is not a panacea the results in increased water yield would be significant.

To obtain results, the MDC must expand its efforts by hiring an additional forestry team and increase the acres managed from 2,500 acres annually. In addition, the Bureau of Forest Development should be given the responsibility for providing technical information and assistance to municipalities to encourage intensive watershed management on all of the municipally owned watershed land.

The Commonwealth of Massachusetts

IN THE YEAR ONE THOUSAND NINE HUNDRED AND EIGHTY-

AN ACT RELATIVE TO THE ESTABLISHMENT AND COORDINATION OF AN INTENSIVE WATERSHED MANAGEMENT PROGRAM ON METROPOLITAN DISTRICT COMMISSION AND DIVISION OF FOREST AND PARK LAND IN ORDER TO INCREASE WATER YIELDS.

Be it enacted by the Senate and House of Representatives in General Court assembled, and by the authority of the same, as follows:

SECTION 1. Section 2 of Chater 21A of the general laws as added by Chapter 806 of the Acts of 1974 is hereby amended by the addition of the following new clause:

(29) Establish and coordinate an intensive watershed management program on Metropolitan District Commission and Division of Forest and Park land in order to increase and maintain waterflow into the Metropolitan Water District System.

NOTE. – Use ONE side of paper ONLY. DOUBLE SPACE. Insert additional leaves, if necessary.

The Commonwealth of Massachusetts

IN THE YEAR ONE THOUSAND NINE HUNDRED AND EIGHTY-

AN ACT RELATIVE TO THE DUTIES OF THE BUREAU OF FOREST DEVELOPMENT.

Be it enacted by the Senate and House of Representatives in General Court assembled, and by the authority of the same, as follows:

SECTION 1. Section 4F of Chapter 21 of the general laws as added by Chapter 631 of the Acts of 1953 is hereby deleted, and inserted in place thereof is the following new section.

SECTION 4F The Bureau of Forest Development shall under the supervision of the director, with the approval of the commissioner perform such duties as respects forest management practices, re-forestation, development or intensive management of forest or wooded areas under the control of the department, in order to ~~in order to~~ produce income in perpetuity, improve the wooded areas or increase water yield in those areas which are part of the Metropolitan District Commission or municipal watersheds. It shall be responsible for such other duties as are now vested in the Division of Forestry by any general or special law including the providing of technical information and assistance to municipalities.

NOTE. — Use ONE side of paper ONLY. DOUBLE SPACE. Insert additional leaves, if necessary.

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FOREWORD

The House Post Audit and Oversight Bureau was established by Chapter 351, Section 282 of the Acts of 1981. The Bureau conducts performance and program audits under the direction of the House Committee on Post Audit and Oversight.

The report is an objective assessment of Watershed Management in Massachusetts. It is designed to assist state and municipal officials who have the responsibility to oversee the management of watershed lands and surface reservoir water supplies.

This report is intended to serve as a helpful tool for state and municipal officials who have the responsibility to oversee the management of watershed lands and surface reservoir water supplies. It attempts to dispel the long existing theory that good watershed management is a policy of total forest protection by highlighting several scientific studies that prove a direct relationship between decreased water yields and increased vegetative growth.

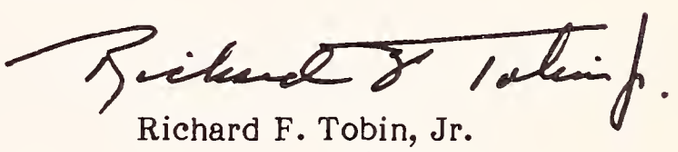
The extent of acceptance of current scientific evidence by MDC, the Executive Office of Environmental Affairs, and municipalities is included in this report to demonstrate the water yield and revenue potential available in a time when shortages of both are facing our state and municipal officials.

We wish to thank the Secretary of Environmental Affairs, John Bewick, the Metropolitan District Commissioner, Richard A. Nylen, the Chief Forester for the Commonwealth, Thomas Quink, the Executive Director of the Water Resources Commission, Emerson Chandler, the State

Cooperative Extension Service Forester, Steven Kalisz, the Metropolitan District Commission Forester, Bruce Spencer and their staffs for the assistance they provided during this audit.

Additionally, we wish to acknowledge the individuals who provided valuable suggestions and assistance to our research including Dr. Donald L. Mader, Professor of Forestry at the University of Massachusetts who conducted the Cadwell Creek Experiment at Quabbin providing the scientific evidence of the water yield benefits resulting from vegetation control on watershed lands.

This study was conducted by Richard M. Sundstrom, Program Analyst, of the House Post Audit and Oversight Bureau.



Richard F. Tobin, Jr.
Director

INTRODUCTION

Over one-half of the Commonwealth's 5.8 million residents receive their daily water supply from either the Metropolitan District Commission (MDC) Reservoir System or one of the ninety-five municipally owned reservoir systems.

Surface reservoir systems rely on the impoundment of surface and subsurface water into natural or man-made basins from drainage areas called watersheds. These watershed land areas are the vegetation covered basin areas over and under which water makes its way into a stream or river and eventually into a surface reservoir. They range in size from several hundred acres to approximately 100,000 acres for the MDC Quabbin Reservoir watershed.

This study is an analysis of the change in the vegetative growth on our state and municipally owned watershed lands resulting in the reduction of water yield into our reservoir systems.

During this century, a combination of public policy decisions and economic factors have changed the vegetative growth on our watershed lands from low evapotranspiration vegetation such as, farm crops and forage lands, to high water consuming forests of dense trees.

The industrialization of the Commonwealth and the non-competitiveness of small scale farming resulted in wholesale farmland abandonment followed by natural reforestation primarily with northern hardwoods (oak, maple, birch) and to a lesser extent with conifers such as white pine or hemlock.

In the 1930's, vast plantations of red pines, because of their resistance to disease, were planted around the MDC and municipal reservoirs and along their riparian zones or stream beds. The Civilian Conservation Corps planted the pines in six foot blocks in an effort to limit erosion and act as a wind screen to stop litter and leaves from blowing into the water. Forty years later, professional foresters are in agreement that most of these plantations are in an unhealthy condition because of overcrowding. Also, red pine has very little market potential from a timber standpoint while consuming a large amount of moisture.

FIGURE 1

Red pine plantation surrounding a municipal reservoir.

In addition, a public policy of total forest protection on watershed land, developed in Europe, and carried over to this country has resulted in increases of over seventy percent in the amount of Massachusetts' watershed land densely forested by large trees.

Scientific analysis of the effect on water yield resulting from a change in land types from open space to forest covered are included in this study in order to compare the water yield of a watershed management program of total forest protection versus an intensive watershed management program of extensive vegetation control, including a professionally supervised, revenue producing, timber harvest.

I. WATER SUPPLY SHORTAGES

A. Background

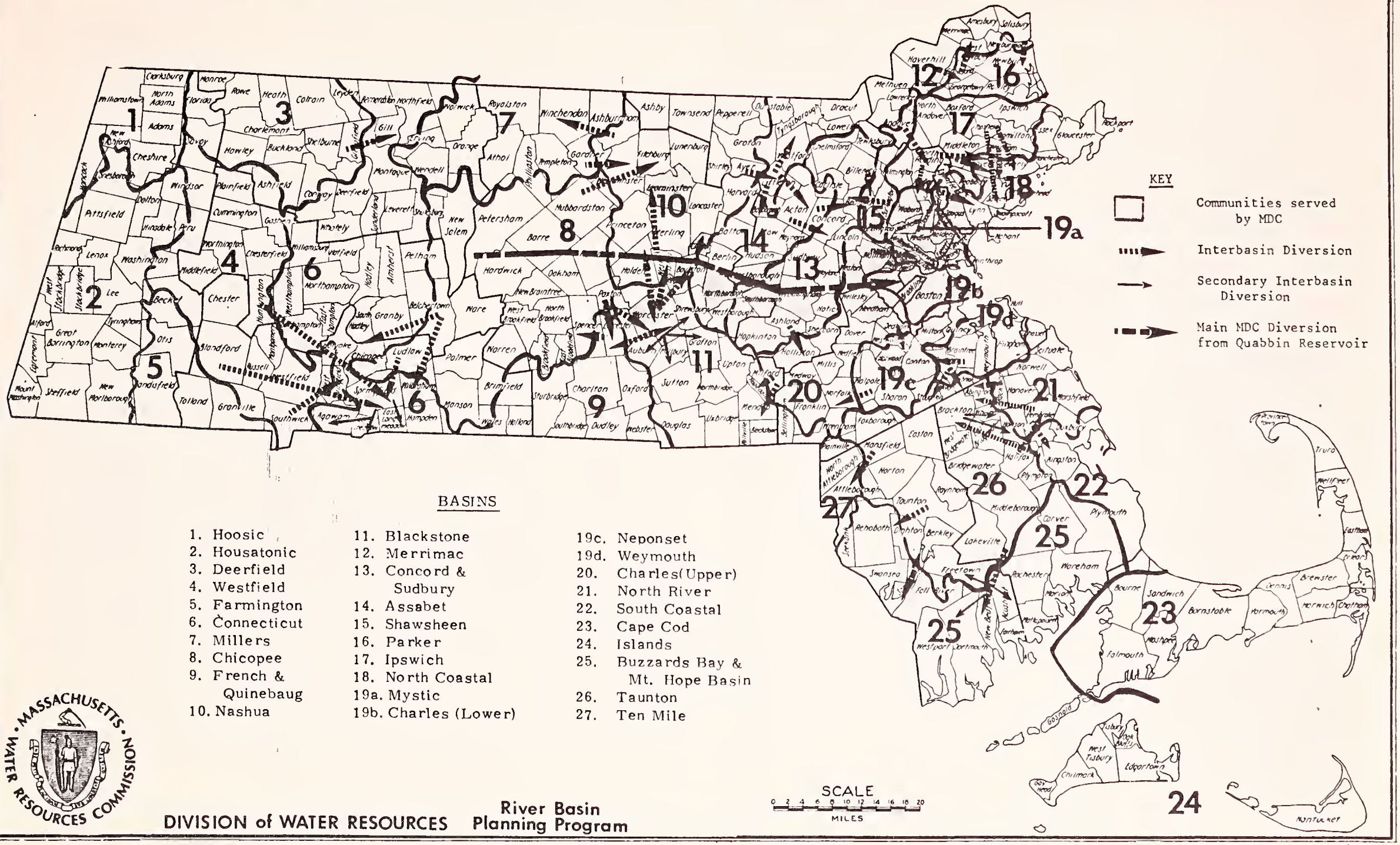
The Commonwealth faces continued water supply shortages. Every citizen by virtue of his place of residence or occupation will be affected in the years to come. Our fabric of life, as well as the industrial and recreational opportunities which insure the entire economy and well being of our state requires an adequate water supply.

Within the next ten years, it is conceivable that the majority of the state's population could face water shortages ranging from limited to crisis proportions. Some communities already have been forced to close contaminated wells, shut off the pumps on dry reservoirs, institute outdoor water use bans or rely on the Metropolitan District Commission System to meet their short term emergency needs, despite a decade of above average precipitation.

The numerous water shortages during the past several years foreshadow future problems which will develop if we continue to overconsume our limited water supplies and we encounter average or below average rainfall.

During the past two years, 38 municipalities have declared water emergencies under the powers granted by Chapter 40 of the General Laws. These communities are designated on the attached maps. Map-1 highlights the MDC member communities and others allowed to purchase water from MDC on an emergency basis. Map-2 highlights communities such as Amherst, Westboro, Marshfield, and Provincetown which experienced shortages to some degree. Map-3 highlights those communities projected to have supply deficits by the year 1990.

PERMANENT INTERBASIN TRANSFERS of WATER SUPPLY – 1980



BASINS

1. Hoosic
2. Housatonic
3. Deerfield
4. Westfield
5. Farmington
6. Connecticut
7. Millers
8. Chicopee
9. French & Quinebaug
10. Nashua
11. Blackstone
12. Merrimac
13. Concord & Sudbury
14. Assabet
15. Shawsheen
16. Parker
17. Ipswich
18. North Coastal
19a. Mystic
19b. Charles (Lower)
19c. Neponset
19d. Weymouth
20. Charles(Upper)
21. North River
22. South Coastal
23. Cape Cod
24. Islands
25. Buzzards Bay & Mt. Hope Basin
26. Taunton
27. Ten Mile

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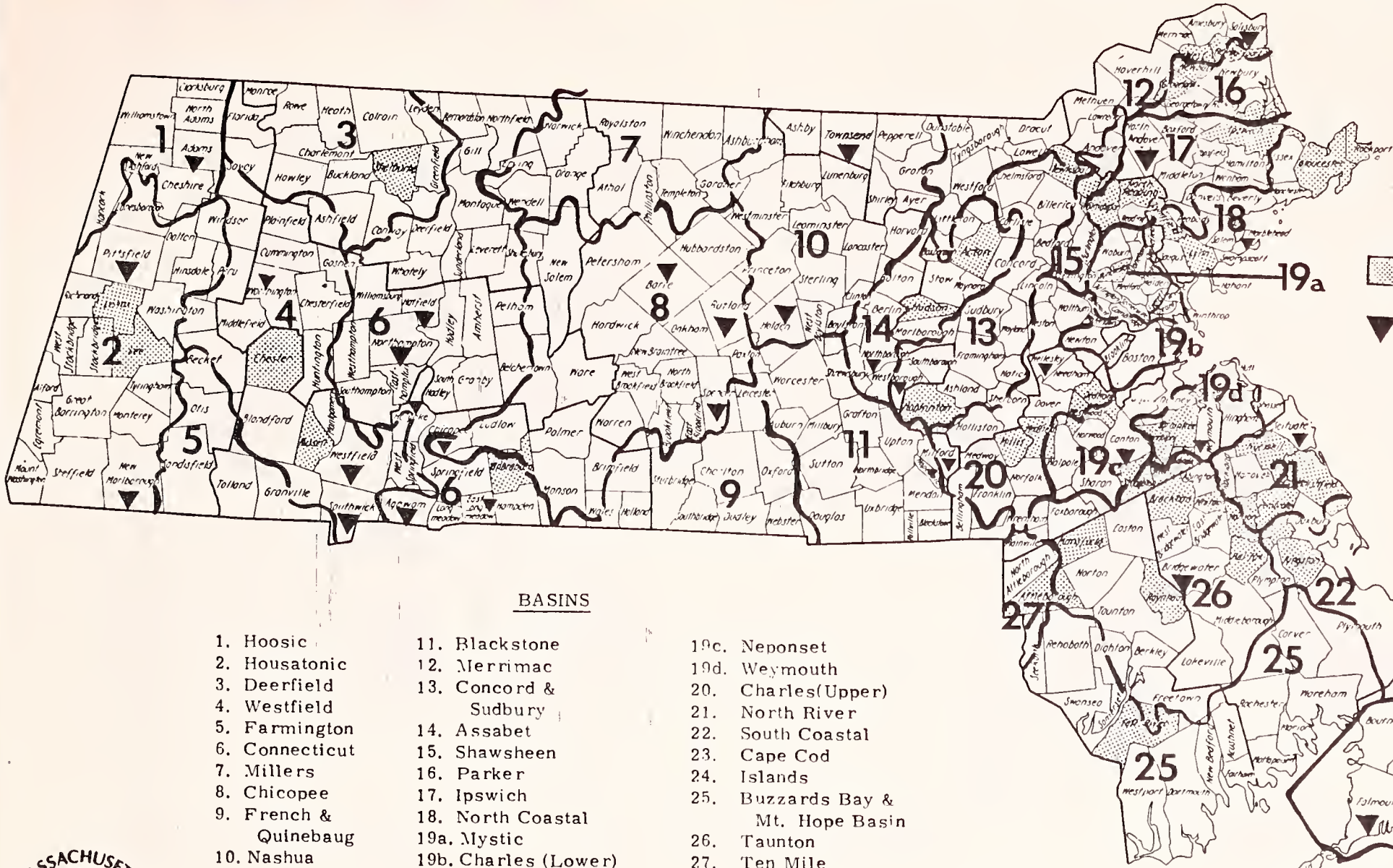
Figure 2 Map 1

COMMUNITIES with CHAPTER 40 WATER EMERGENCY DECLARATIONS or VOLUNTARY WATER RESTRICTIONS – 1981



KEY

Chapter 40 Water Emergency Declarations
42 communities

Voluntary Restrictions
30 communities
(partial list)

BASINS

1. Hoosic
2. Housatonic
3. Deerfield
4. Westfield
5. Farmington
6. Connecticut
7. Millers
8. Chicopee
9. French & Quinebaug
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27. Ten Mile

SCALE
0 2 4 6 8 10 12 14 16 18 20
MILES

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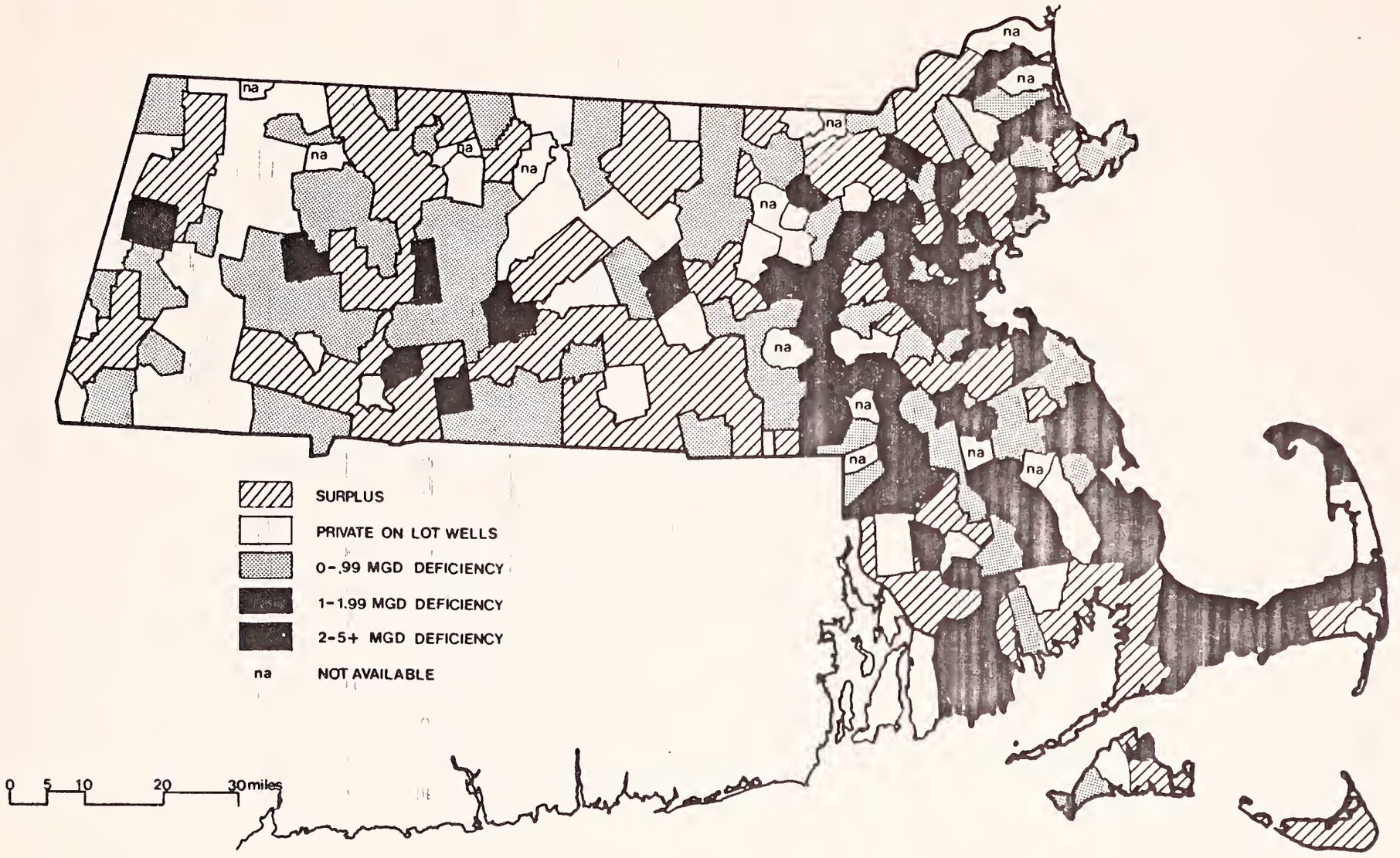
Figure 3 Map 2

PROJECTED NEEDS: 1990



DISPLAY #2

Source: *Massachusetts Water Supply Policy Study*, Executive Office of Environmental Affairs.

Figure 4 Map 3

More than 45 percent of the communities in the Commonwealth rely partially or totally on surface water reservoirs to meet their water needs. Almost 60 percent of the state's population receives their water from these sources.

In addition to Boston and the MDC communities, the major population centers relying on surface systems include New Bedford, Fall River, Brockton, Lowell, Lawrence, Haverhill, Fitchburg, Leominster, Springfield, Pittsfield, and Worcester. Of these communities, Fall River, Worcester, Brockton and Leominster have already experienced supply problems and, depending upon the rainfall during the next ten years, the list may grow considerably.

Only Springfield of the state's major surface water population centers appears to have a more than adequate water supply for the foreseeable future.

B. Metropolitan Water District/MDC

Over the last 100 years, as the population of the Metropolitan Boston area increased, the demand for water grew proportionately and the search for new supplies moved westward. The system began with Jamaica Pond and expanded to Lake Cochituate in 1848. In 1895, the Metropolitan Water District (MWD), consisting of Boston and twelve other communities was established. Shortly thereafter, the Wachusett Reservoir and Aqueduct was constructed.

In 1926, work began on the Quabbin Reservoir and was completed in 1939 with the impoundment of the Swift River. Located within a 186 square mile watershed area, the reservoir has a capacity of 412 billion gallons of water. It provides over 50% of the MWD's daily needs.

The MWD currently has 34 member communities and has over the past several years sold water to ten others. Approximately 2,300,000 people or 40% of the state's population rely on the MWD/Quabbin System for all or part of their water supply.

Engineers have estimated that based on the design of the system a "safe daily yield" would be 300 million gallons. For the past five years, this safe yield has been exceeded by an average of 20 million gallons per day. The peak daily consumption for the system was 479 mg on August 1, 1975.

Continued consumption above safe yield has not yet created a major problem for the MWD because precipitation has been above average for the past ten years.

A recurrence of the 1961-65 drought, which reduced Quabbin's level to 45% of capacity, would at today's consumption rates decrease the level to 25% of capacity. MWD officials believe that all but 10% of the Quabbin water is available for consumption.

The worst case scenario for the Quabbin Reservoir/MWD running dry would be five or six years of average precipitation followed by a drought of 1961-65 severity while consumption continues to exceed safe yields. This scenario is predicated on the current MWD membership and does not take into consideration the growing number of cities and towns which are looking to the MWD on an emergency or permanent basis.

A Massachusetts Water Supply study predicted that 24 other metropolitan communities might have to rely totally or in part on the system by 1990 because of shortages or contamination of their own supplies.[1] These communities would need an estimated 70 mgd to meet their 1990 projected needs. If this prediction does come true, the MWD will have

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[1] U.S. Army Corps of Engineers, News Reports: Water Demand Study, Eastern Massachusetts Region, 1974.

to pursue every possible alternative to prevent the possibility of the worst catastrophe ever to face the Commonwealth.

C. Water Shortage Solutions

Recognizing the reality of continued water shortages, both state and municipal governments are proposing or actually taking remedial steps in order to curtail consumption or increase supplies. The steps have fallen into two categories:

1. Capital Intensive Improvement Programs
   - Leak detection and the repair of pipes and meters
   - Construction of water filtration plants
   - The purchase of reservoir sites
   - Drilling of municipal wells
   - Proposed diversion of rivers and streams into existing reservoirs.
   - Activating dormant wells and reservoirs
2. Conservation Improvement Programs
   - Regulation of business and industries
   - Bans on outdoor usage of water
   - Public education programs
   - Marketing of water restriction devices
   - Revamping of rate structures.

The cost of these measures ranges from little or no cost to institute an outdoor water ban, to millions of dollars to divert the Connecticut River into the MDC system.

D. The Water Shortage Solution Not Being Pursued

A partial solution to our surface water supply problems is available. That solution is an intensive watershed management program.

It is HPAB's position that intensive watershed management on state and municipal watershed land has the potential of increasing water yield by billions of gallons annually while generating needed revenue dollars for fiscally hard pressed communities through the harvesting of marketable timber.

FIGURE 5

Intensively managed riparian zone on Quabbin Reservoir watershed land.

FIGURE 6

Timber harvesting on watershed land.

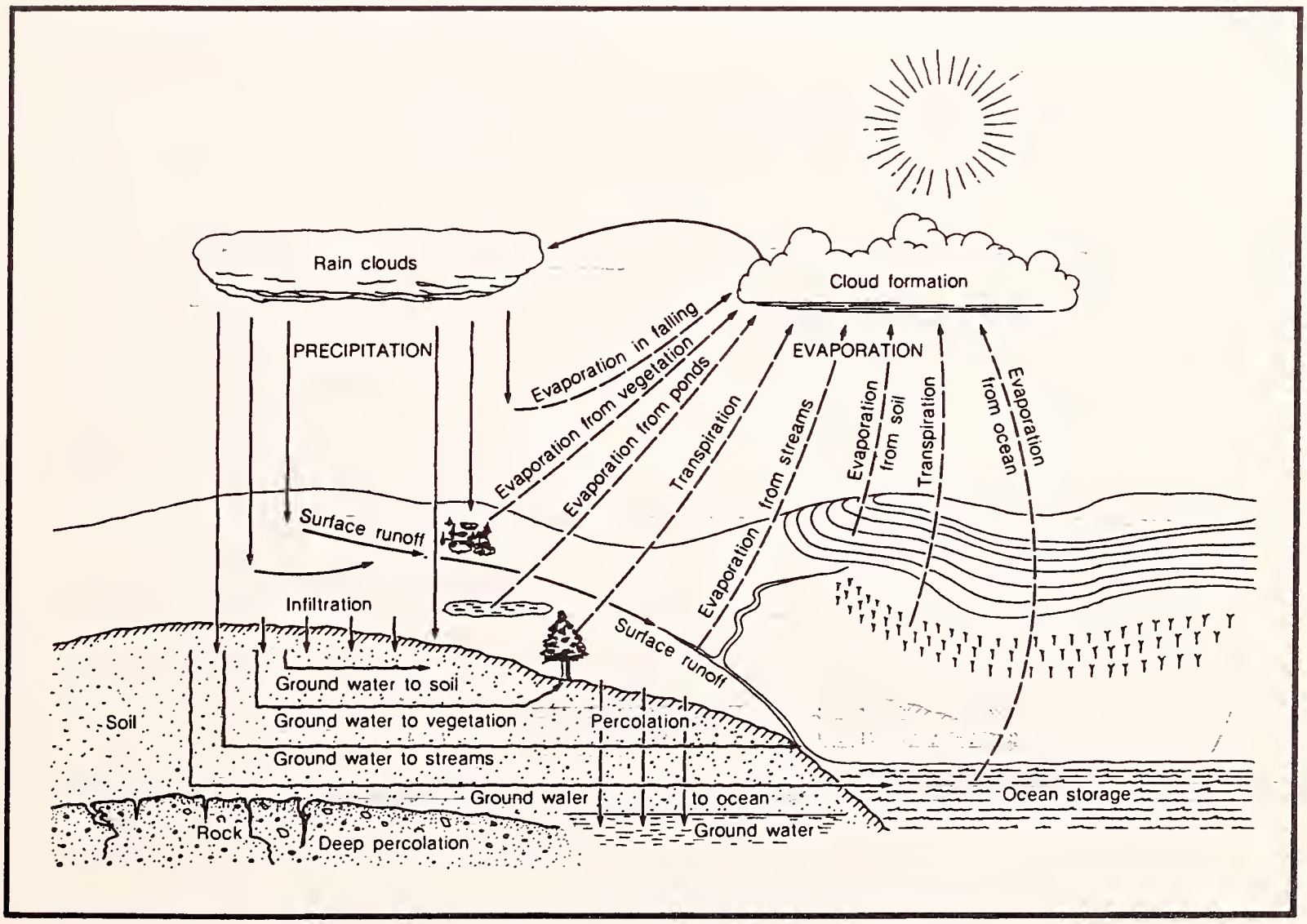
This report utilizes the findings of scientific studies to support HPAB's position, and based on the data from these studies, examines the current status and future potential for an intensified statewide watershed management program.

Intensive watershed management is not a total solution, but it can yield tangible results for MDC, the State Division of Forests and Parks and many municipalities with sizeable watershed land holdings. Consideration of intensive watershed management should be a part of any comprehensive water resource plan.

The delivery and source of our daily water supplies is a subject to which we give little thought. In order to more fully understand the thrust of this study, it is necessary to provide a basic explanation of the source and interrelationship between ground and surface water and what is referred to as the hydrologic cycle.

Figure 7 below is a fundamental description of the process by which precipitation reaches the ground and moves through surface and subsurface drainage systems.[2]

FIGURE 7



[2] Council on Environmental Quality, Executive Office of the President, 1981.

Energy from the sun is the driving force in the cycle. This energy evaporates water from the ocean's surface, into gaseous or vapor form, in an amount which exceeds the precipitation falling directly upon the surface. This excess vapor is driven by wind patterns from the ocean to the land. Once over land, the vapor is influenced by heat from the sun, by air and water temperature, relative humidity, barometric pressure, wind movement, altitude and quality of the air.

Precipitation results when water vapor condenses onto particles in the atmosphere. Gravitation forces the particles to fall to the earth's surface with temperature determining the type of precipitation: rain, snow, sleet, or hail. This downward movement of the cycle represents the conversion of vapor into precipitation.

It is at this point that the hydrologic cycle becomes a complicated one, and where man's ability to influence the runoff into our reservoirs comes into play. The variables which will affect the amount of watershed runoff into a surface reservoir are: size and type of rainfall, season of the year, weather, size and shape of the watershed, kind and depth of the soil and the vegetation on the watershed.

This study deals primarily with forested watersheds as opposed to those covered with brush or grass, or urban development. The hydrologic cycle and streamflow in forested areas are influenced by several critical processes: interception, infiltration, storage, evapotranspiration and drainage. Across the Commonwealth, if precipitation in any form were allowed to fall on bare ground, the increased streamflow would amount annually to ten inches or more of precipitation, the equivalent on a per acre basis of more than 250,000 gallons. Consequently, the density of forest cover will result in less streamflow.

Figure 7 illustrates that precipitation falling to the earth encounters forest cover. Some of the precipitation is intercepted and evaporates. Some reaches the soil and is absorbed into plant root systems then moves up into the stems and leaves and eventually is lost by transpiration. Some, depending upon the season, reaches the soil and becomes runoff into a stream and eventually into the surface reservoir. Finally, some moisture filtrates into the ground and becomes subsurface ground water eventually flowing into the surface reservoir.

The remaining sections of this report document scientific studies showing the magnitude of interception and evapotranspiration in our forested watersheds; the potential increased water yield from intensive watershed management; the active watershed management programs in the state; the lack of a coordinated watershed management program and the statewide potential for watershed management on municipal lands.

III. TOTAL FOREST PROTECTION

SACANDAGA RIVER CASE STUDY 1911-1962

A. Summary

The Sacandaga River Case Study offered a unique opportunity to witness, over a 39 year period, the effect of total forest protection on water yields.[3] A 7.72 inch or 23 percent decrease in river flow was documented through stream gaging data.

This study proves that uncontrolled basal area growth on a watershed will decrease yield by at least 20% over a period of time. Removal of large numbers of conifers by nature or man, eliminates the interception influence on yields and is demonstrated by the startling dormant season yield increase observed in the New York Study.

This case demonstrates the negative yield impact which will result from a continued policy of total forest protection such as practiced by most Massachusetts municipalities.

B. Introduction

Total forest protection is the prohibition of all timber harvesting or recreational activities on municipal watersheds. This practice was initiated in Europe to prevent erosion which caused heavy sedimentation of water systems. The practice carried over to this country in the early part of this century when large tracts of land were being acquired by municipalities for watersheds in the Commonwealth.

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[3] Effects of Long-Term Protection Policy on Water Yields, Arthur R. Eschner, State University College of Forestry, Syracuse, N.Y. p. 9

The long term practice of total forest protection has now been found to result in a considerably decreased water yield while increasing the forests susceptibility to natural disasters such as blow downs from wind or snow storms, or devastating insect infestations. The analysis of the Sacandaga River Watershed Case Study, which follows, scientifically demonstrates the results of a total forest protection policy on a New York watershed very similar in climate, topography, forest cover etc., to those in Massachusetts.

C. Background

In the early nineteen hundreds, a constitutional amendment was enacted in New York establishing the Adirondack Park-Preserve which stipulated that the area be totally protected against fires, logging or timber harvesting.

Located within the preserve, is a 491 square mile watershed, which drains into the Sacandaga River, above the United States Geological Survey's stream gaging station at Hope, New York. The following table gives a complete physiographic description of the watershed.

TABLE 1

Sacandaga Watershed Physiographic Description

Geology	- Dense, crystalline, metamorphosed rock with a sandy loam to loamy sand texture.
Elevation	- Rolling hills with steep slopes between 1500 and 2000 feet elevation.
Climate	- Cool and humid, average temperature 40°F. Average annual precipitation 45". Seasonal snowfall between 80" and 130".
Vegetation	- Northern hardwoods, sugar, maple, yellow birch beech, conifers, red spruce, hemlock, black spruce, white pine and tamarack.

D. Forest Growth 1912-1952

On the basis of tree ring analysis and stand measurements on 47 selected forest stands, detailed information was compiled relating to the basal area increase in square feet per acre, since 1912 for all species of conifers and hardwoods.

From 1912 to 1932, the estimated basal area per acre of the conifers and hardwoods increased at a rate to be expected. For purposes of the study, a special estimate of the basal area per acre was made in 1952. Prior to this, on November 25 and 26, 1950 a snowstorm with hurricane force winds in excess of 83 miles per hour struck the watershed with devastating results. The forest contained an unusually large number of weak and defective trees, resulting from 40 years without any type of management or thinning program, which were unable to withstand the force of the storm, where a strong vigorous growing tree might have survived.

The effect of this storm on the basal area per acre of conifers became evident in the 1952 analysis (Table 2) which showed considerably less growth over the 20 year period 1932-1952 than was expected following the twenty year increase from 1912 to 1932.

The basal area per acre of pole timber, conifers in hardwood, and mixed wood stands actually decreased over the 1932 to 1952 period. Stands of conifer pole timber were particularly susceptible to extreme damage from a high wind snowstorm such as the November 25 and 26, 1950 storm because of poor growth and quality caused by overcrowding and lack of thinning, resulting from the constitutional prohibition on logging or timber harvesting, in effect in the Adirondack Preserve.

TABLE 2

Mean Basal Area in Square Feet Per Acre in Trees of Evergreen Species Larger Than 5.6 Inches D.B.H.[4]

Type	Stand Size Class	Year 1952	1932	1912
Pioneer Hardwoods	Seedings & Saplings	1.62	.30	0
	Poletimber	2.98	1.42	.42
Northern Hardwood	Poletimber	2.06	4.06	3.65
	Light Sawtimber	30.54	27.40	19.64
	Medium and Heavy Sawtimber	12.46	10.72	7.13
Mixed Wood	Seedings & Saplings	25.06	24.49	13.50
	Poletimber	34.96	35.02	24.62
	Light Sawtimber	69.65	52.84	28.90
	Medium and Heavy Sawtimber	29.35	33.36	30.23
Softwood	Seedings & Saplings	40.07	38.58	21.64
	Poletimber	103.02	94.34	61.92
	Light Sawtimber	79.75	62.50	26.65
	Medium and Heavy Sawtimber	106.77	95.48	65.39

[4] Ibid.

E. Water Yield 1912-1962

Since 1912 scientists have been able to measure streamflow data on the Sacandaga River by utilizing the U.S. Geological Survey's stream gaging station near Hope, New York.

From 1912 to 1950 a significant downward trend in river waterflow was detected, factoring in the relative precipitation in the watershed area. Based on the trend, it was possible to mathematically predict the streamflow for the future years 1950 to 1962.

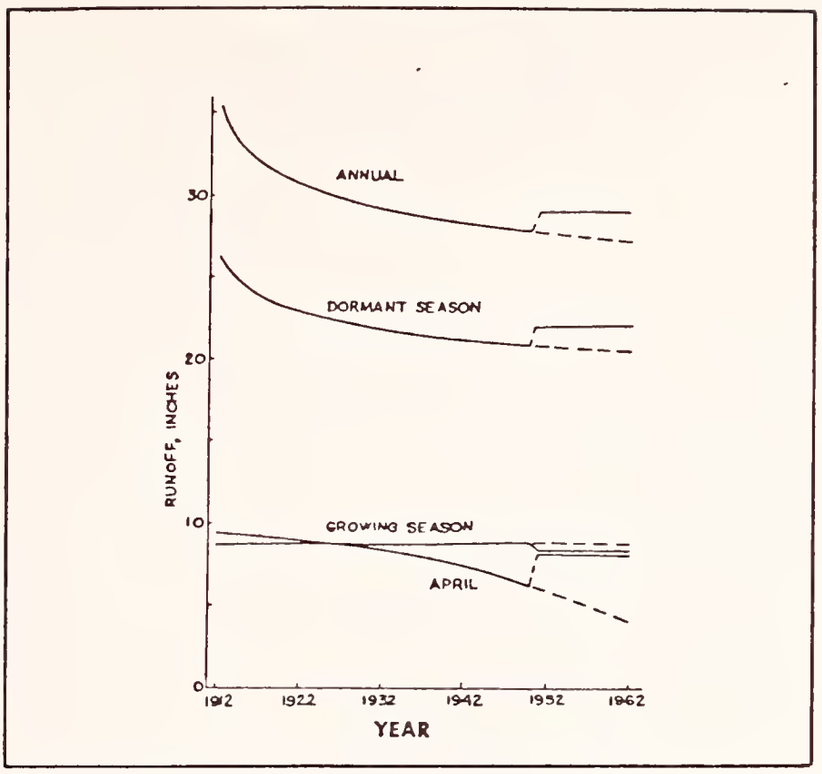
The unaccounted for variable factor in the mathematical progression was the November 25 and 26, 1950 windstorm. The 83 mile per hour gusts blew down large stands of conifer pole timber with the result being an immediate decrease in the basal area of the watershed.

Figure 8 which follows shows the annual dormant season and average monthly runoff on the watershed over the 1912 to 1962 period of time. The broken lines are the runoff trends extended from 1950 to 1962 as opposed to the actual runoffs.

Utilizing average temperature and precipitation variables, it was determined that over the 39 year period 1912 to 1950 there had been a 7.72 inch or 23 percent decrease in runoff as a result of a 75 percent increase in the basal area of the watershed.

The major causes of the decreased yield can be attributed to interception and evapotranspiration. Scientific studies have shown that dormant season interception of rain and snow by conifers amounts to 20%. The removal of a large portion of the basal area by the November 1950 storm lessened the interception influence on the watershed and resulted in the significant increase in dormant season flow (Figure 8) in the years following.

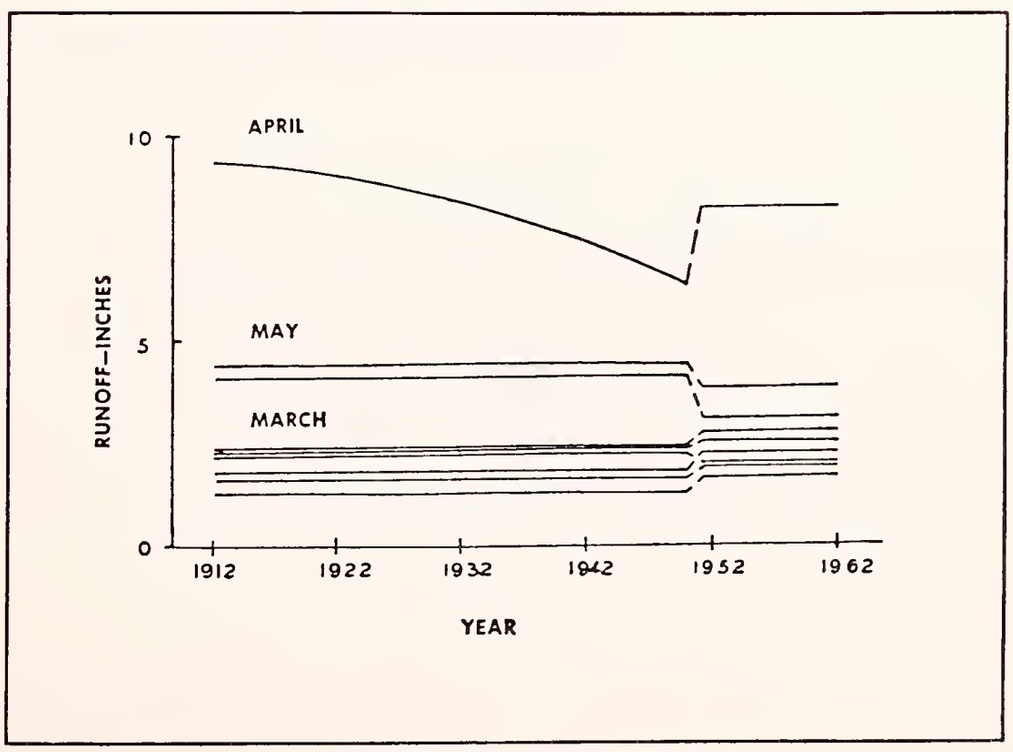
FIGURE 8



Annual, dormant season, and growing season runoff in relation to time. Dashed lines are the 1912 to 1950 equations extended.

Figure 9 indicates the significant increase in average monthly runoff flow following the 1950 storm.

FIGURE 9



Average monthly runoff, October through June.

IV. INTEGRATED WATERSHED MANAGEMENT PROGRAM

CADWELL CREEK CASE STUDY

A. Summary

The Cadwell Creek Study, utilizing three different vegetation control treatments, proved that increased water yields not only can be achieved by municipalities but can be achieved in a cost beneficial manner.[5] A 19% increase in water yield above expectations was documented over a four year period for a small subwatershed area which had typical, geophysical, topographical, and vegetative characteristics commonly found in most watershed areas of the Commonwealth.

The study concluded that maximum water yield benefit can be derived by removing all woody vegetation from the riparian zone. Further, the practice of low density management on upland areas will increase the flow of water into the riparian zone.

This study demonstrated a dramatic increase in water yield during the growing season when water supplies are at their lowest because of high temperatures and extreme evapotranspiration.

B. Introduction

During the 1940's and 1950's a number of scientific investigations were conducted to demonstrate that removal of varying amounts of vegetation would result in increased water yields on forest covered watersheds. Studies dealt with the manipulation of soil moisture in forested areas by

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[5] Integrated Watershed Management: An Alternative for the Northeast, Research Bulletin No. 664 by Brian Mrazik, Donald L. Mader and William P. MacConnell, University of Massachusets, College of Food and Natural Resources, January 1980, pp. 50.

vegetation control, while others dealt with the role of stream bed or riparian vegetation removal in the regulation of runoff. However, none tested the practical feasibility of combining these various scientific hypothesis on an actual forested watershed of a size and scope which could be managed by a municipal watershed manager or forester.

In the late 1950's state and federal officials developed a cooperative program in conjunction with the University of Massachusetts College of Agriculture, the United States Geological Survey and the Metropolitan District Commission to test the vegetation manipulation theories on an actual watershed in the Northeast part of the United States. The 1,798 acre Cadwell Creek subwatershed of the Quabbin Watershed was selected.

The gently sloping V-shaped valley (Figure 10) with soil consistencies ranging from sand, to sandy loam, to rocky, had a mixed forest vegetation of hardwoods including red oak, black oak, red maple, ash and beech. Also, conifers of white pine, red pine and hemlock, and an undergrowth vegetation of laurel, blueberries and ferns (Figure 11).

Annual precipitation averaged between 36" and 44" while the yearly average temperature was 48^{o} Fahrenheit.

In 1961, the U.S. Geological Survey installed two weirs (Figure 12) or streamflow measuring dams in the creek. One weir was to measure streamflow for the entire 1,798 acres. The other weir was to measure a 421 acre subwatershed, at the creek headwaters, which was to be the experimental treatment area.

FIGURE 10

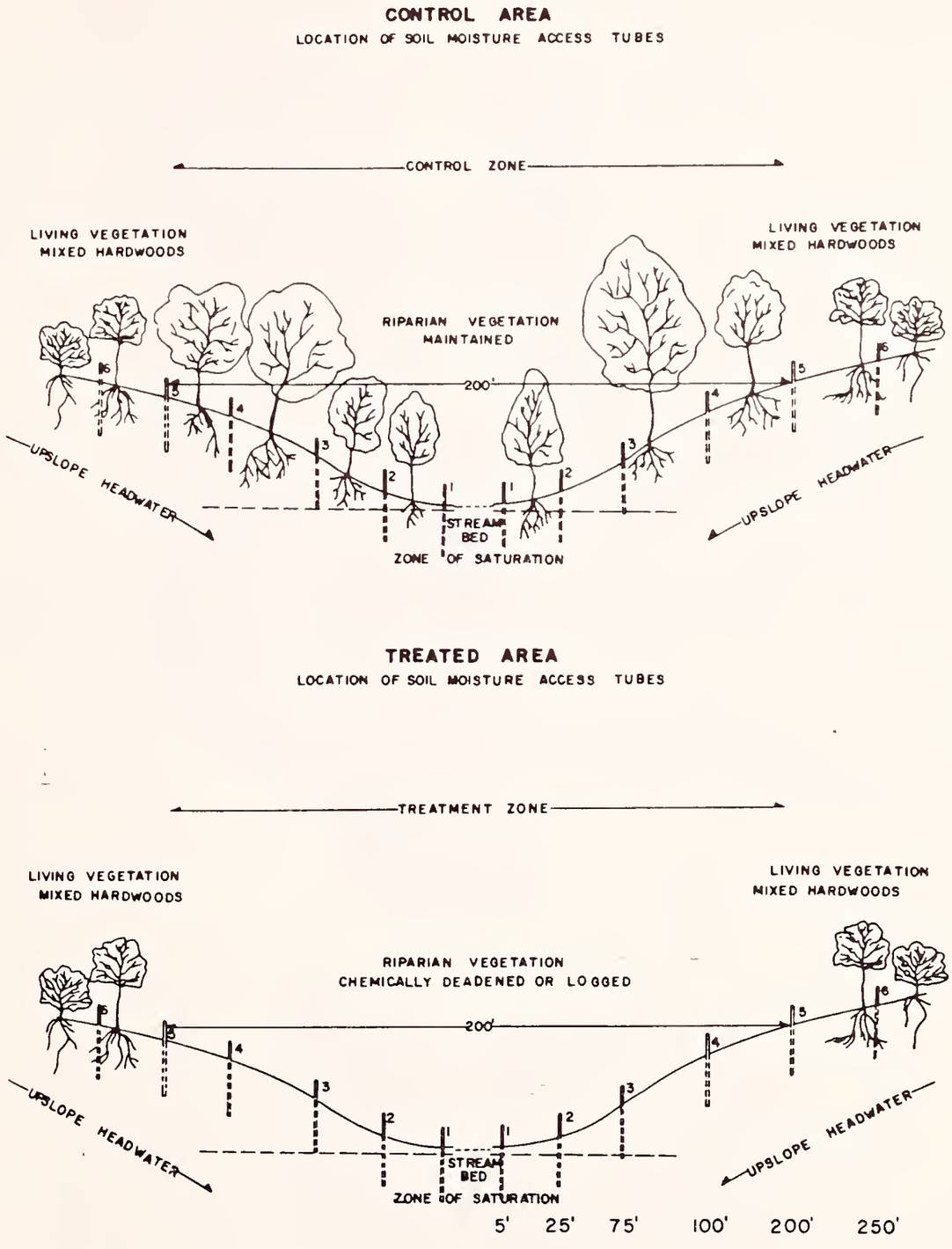
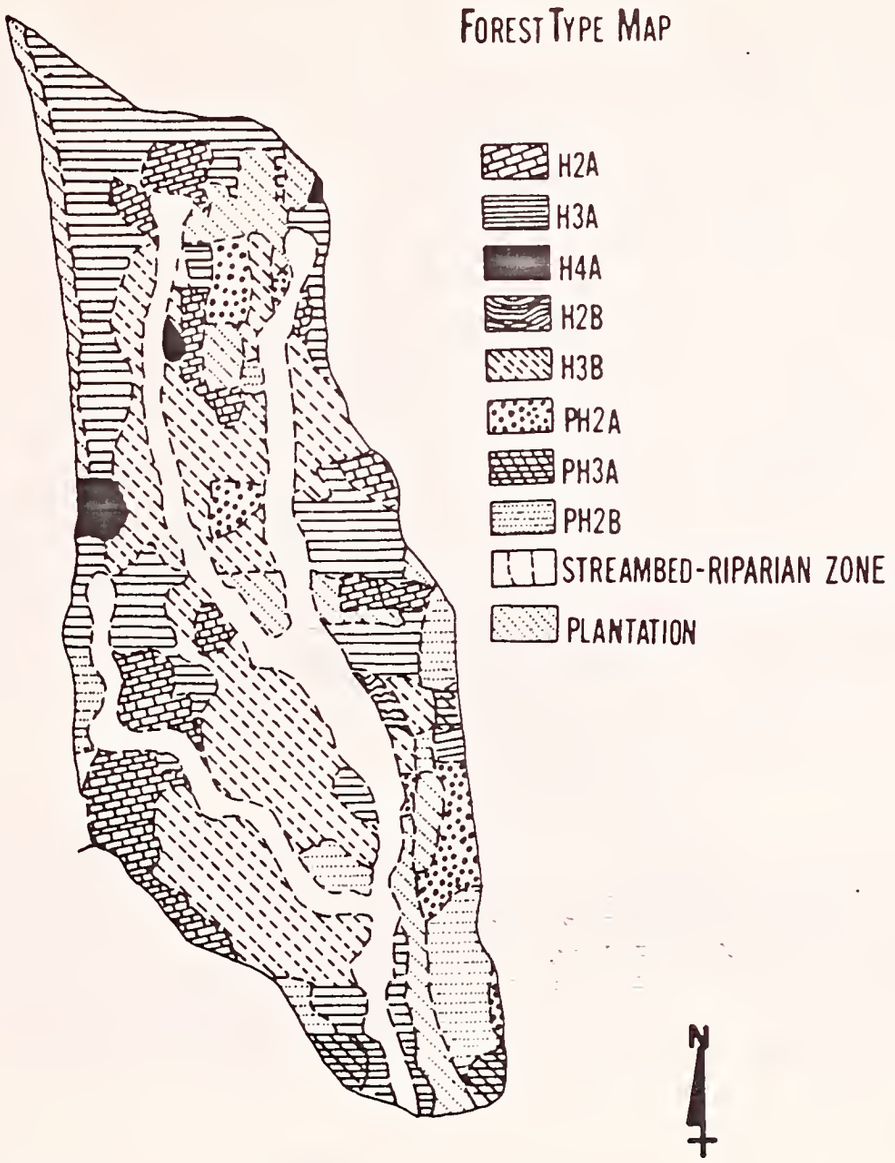


Diagram of typical transects of moisture tubes across the valley of Cadwell Creek in the treated and untreated area.

FIGURE 11



SYMBOL	FOREST TYPE
H_2A	Mixed hardwoods, 20 to 40 feet tall, 80 to 100% crown closure.
H_3A	Mixed hardwoods, 40 to 60 feet tall, 80 to 100% crown closure.
H_4A	Mixed hardwoods, 60 to 80 feet tall, 80 to 100% crown closure.
H_2B	Mixed hardwoods, 20 to 40 feet tall, 60 to 80% crown closure.
H_3B	Mixed hardwoods, 40 to 60 feet tall, 60 to 80% crown closure.
PH_2A	Mixed pine and hardwoods, 20 to 40 feet tall, 80 to 100% crown closure.
PH_3A	Mixed pine and hardwoods, 40 to 60 feet tall, 80 to 100% crown closure.
PH_2B	Mixed pine and hardwoods, 20 to 40 feet tall, 60 to 80% crown closure.
Plantations	Are red and white pine, pure and mixed, 20 to 40 feet tall, planted at a 4 x 4 or 6 x 6 feet spacing.

Forest cover type map for the upper treated subwatershed of Cadwell Creek.

FIGURE 12

Ninety degree V-notch sharp-crested weir and concrete Trenton cut-off wall of gaging station for the treated subwatershed of Cadwell Creek.

For a six year period, data was collected on stream flow, soil moisture content of the riparian zone, air and water temperature and precipitation.

In 1967, three different vegetation removal operations commenced on the 421 acre subwatershed. First, approximately 700,000 board feet of hardwood and pine were harvested by a commercial patch clearing logging operation on the upper slopes (Figure 13). The income from this operation totalled $11,000, a somewhat lower amount than would be normally generated due reportedly to the small diameter of the harvested trees.

FIGURE 13

Clear cut patch created by group selection harvesting on the treated subwatershed of Cadwell Creek.

Assuming that all of the timber harvested could only be used for pallet production because of its relatively small size, at current stumpage prices the income realized would be in the vicinity of $65,000.

Secondly, all large vegetation within 100 feet of the stream channels was chemically deadened. A total of 49 acres of stream banks was treated in this way. Several red pine plantations within the experimental area were likewise very heavily thinned in the same manner.

Lastly, mist-blown herbicides were applied to all low growth vegetation so that all vegetation was removed within 200 feet of the channels.

To summarize treatments, all woody vegetation was deadened or removed within 200 feet of the channels. Mature timber was heavily cut in a patch clearing pattern and red pine plantations were heavily thinned. It was estimated that 64% of the 421 acres received some type of treatment. One-third of the total basal area on the entire subwatershed was removed.

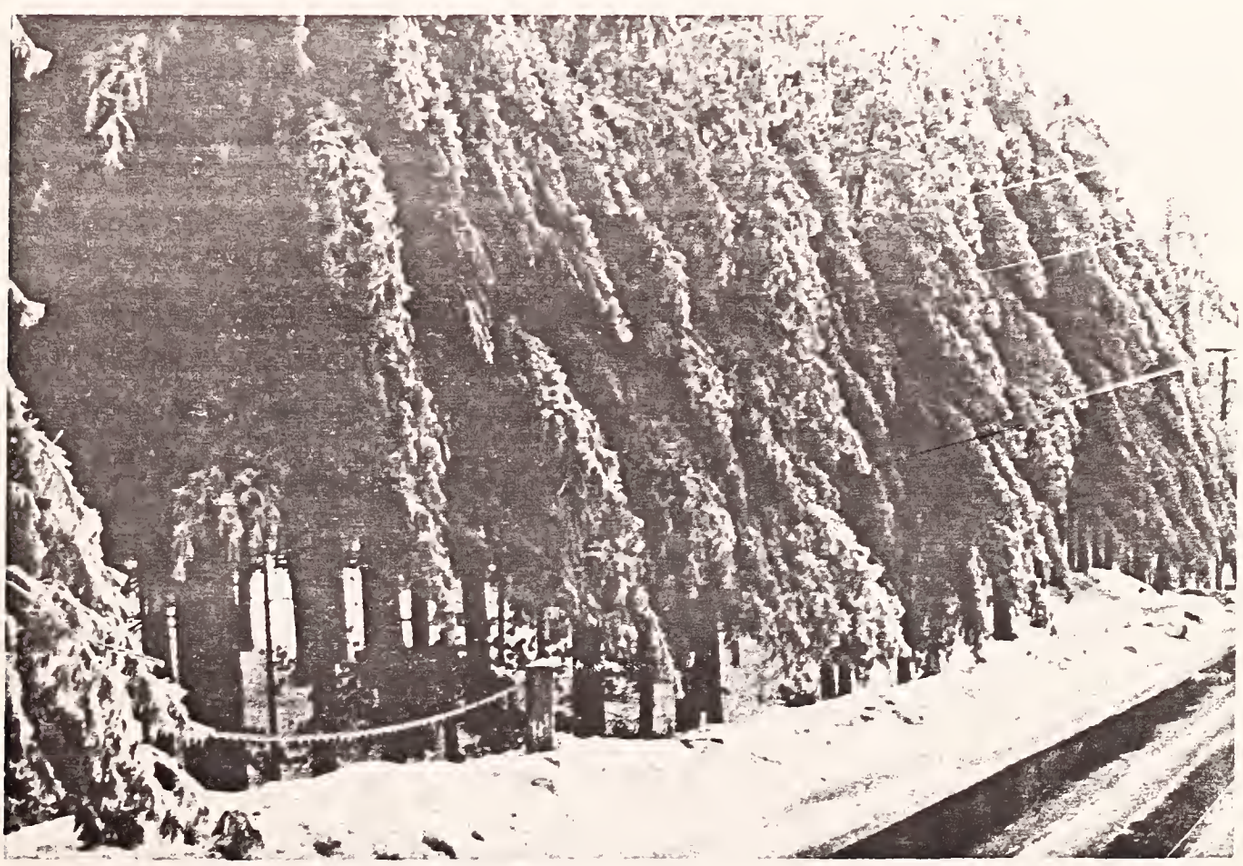
C. Experiment Results

During the spring of the year, increasing temperatures which rapidly melted the snow covering, quickly saturated the soil contributing to a continuous recharging of soil moisture and simultaneous runoff. The lack of stomatal growth and plant activity at this time of year results in little evaporation or transpiration. As such, little variation was found in the soil moisture level of the control area versus the treatment area. However, as soon as trees leafed out soil moisture levels became much lower in the untreated area than in the treated riparian zone.

The Cadwell Creek research on spring time water yield increases was consistent with other study results. It was the opinion of the researchers that the timber patch clearings and heavy red pine plantation thinnings on the upper slopes assisted in maintaining higher soil moisture levels for a longer duration, thereby increasing water movement into the riparian zone and stream channels.

Additionally, other research has proven that conifer plantations intercept up to 20% of the annual precipitation mainly in the form of snowfall. The snow is trapped in the upper crowns and the moisture evaporates into the atmosphere (Figure 14).

FIGURE 14



Upper crown snow interception by red pines surrounding a municipal reservoir.

Table 3 which follows summarizes the annual water yield increases for the 1968-71 period.

TABLE 3

Cadwell Creek — Annual Water Yield

Year	Predicted Runoff	Increased Inches	Percentage Increase	Increased Gallons
1968	18.89	4.07	22 %	44,542,000
1969	27.15	6.10	22 %	66,758,000
1970	18.27	3.59	20 %	39,289,000
1971	23.08	3.11	13 %	34,158,000

Based on a per capita daily consumption rate of 176.6 gallons, the 184,747,000 gallons of additional water yielded from the Cadwell Creek experiment over four years could meet the annual needs of 2,866 citizens.

D. Other Considerations

1. Cost/Benefit of Vegetation Removal

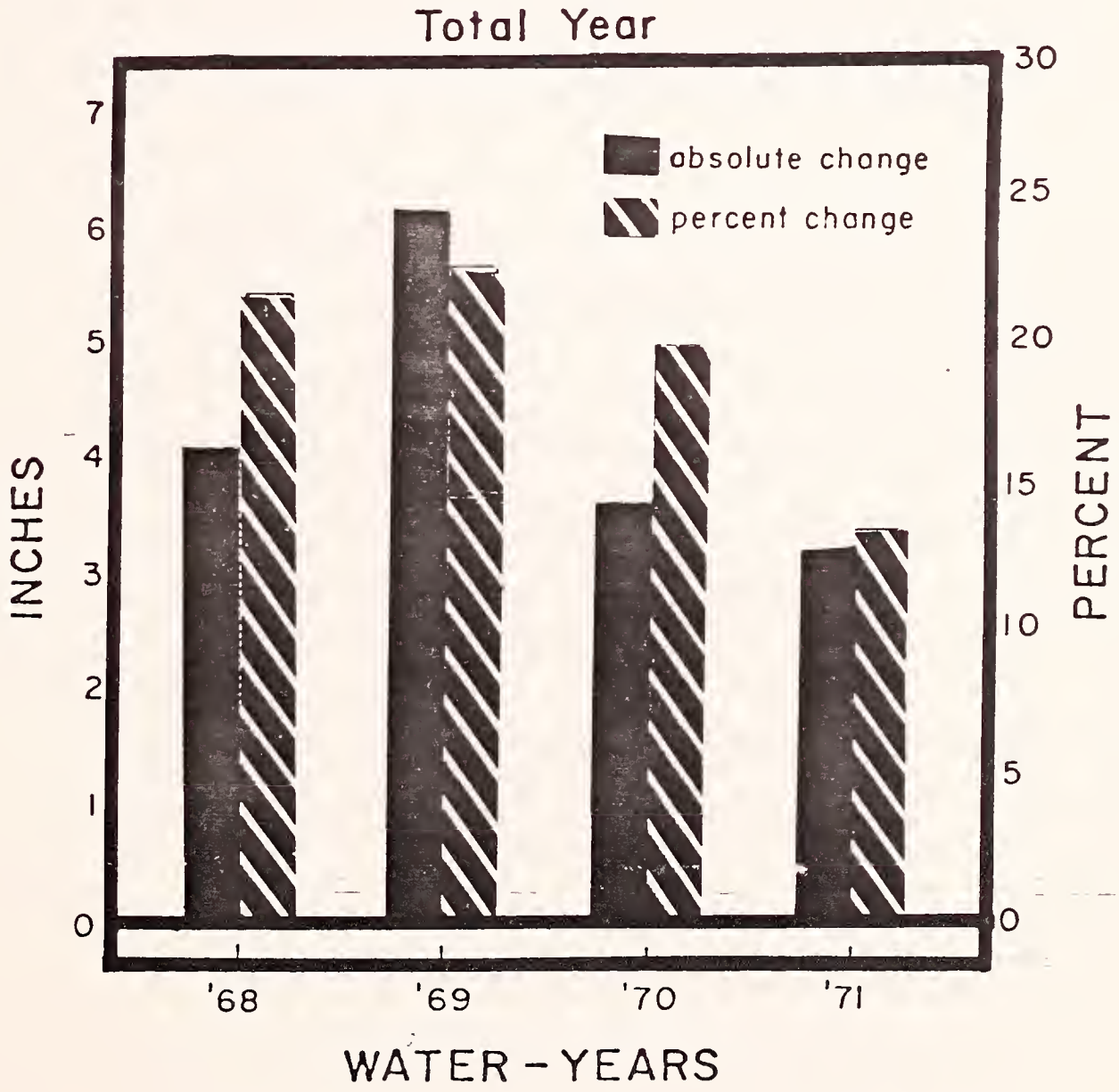
The cost for the program including labor and materials but excluding overhead, amounted to $3,915. As previously mentioned, the commercial timber harvesting generated $11,000 in income. Additionally, the researchers placed a dollar value of $11,084 on the 184.75 million gallons of increased water yield for a total cost benefit ratio of $1 to $5.64.

In the first full year of observation, June 1967 to June 1968, the increased growing season yield amounted to 2.2 inches. The increased yield

for the entire 1968 water year was 4.07 inches or 22 percent greater than expected.

Figure 15 which follows shows the actual yield and percentage increase above expectations for the 1968 through 1971 years. The drop off in the 1971 year to a 13% increase is attributed to a heavy increase in sprout growth in the riparian zone. The drop off demonstrates the necessity for the continued maintenance of previously treated areas.

FIGURE 15



Actual water yield and percentage increase above expectations Cadwell Creek 1968-1971.

2. Herbicide Usage

Regulations promulgated subsequent to the Cadwell Creek Experiment would prohibit the usage of some of the herbicides used in the experiment. Municipalities considering riparian vegetation control would have to do so, by mechanical means or utilize acceptable herbicides.

3. Aestethetics

The deadening of trees by herbicides within one hundred feet of the stream channels left the area with many unsightly dead trees. However, within several years the stems fell to the gournd or were salvaged for firewood and the grasses and ferns regrew in the riparian zone thus producing a meadow-like appearance. Currently, such trees would be removed for firewood or other uses.

4. Water Quality

An important concern of municipal watershed managers is the maintenance of a high quality water supply. The possibility of unhealthy sedimentation rates from timber logging is limited if the operation is properly planned. It will not exert serious negative impacts as evidenced by a Wisconsin study which compared sedimentation rates resulting from various land usages.

The City of Worcester avoids any chance of sedimentation flowing into its reservoirs during timber harvesting by utilizing a team of horses (see Figure 16).

FIGURE 16

Timber harvesting on municipal reservoir watershed land by the use of horses in order to avoid sedimentation.

V. THE EFFECT OF CHANGES IN LAND USE AND VEGETATIVE COVER

During the past seventy years noticeable land use changes have occured in the Commonwealth, as our state's economy evolved from a small farm agricultural base to its current industrialized state. As small scale farming became less economically attractive compared to industrial employment opportunities in the urban areas, a gradual wholesale abandonment of farmland had taken place with an accompanying natural reforestation of previously low evapotranspiration vegetation covered lands.

The Pywell Doctoral Dissertation evaluated the effects of land use changes and vegetative cover on water yield from the Swift River from 1914-1971.[6] Aerial photographs taken in 1936, 1952 and 1971 supplemented by historical records were used to produce maps outlining land use and vegetative cover.

Changes addressed included: farmland abandonment, natural forestation, land clearing for the Quabbin Reservoir construction, the 1938 hurricane and tree planting for watershed protection.

Annual, seasonal and monthly water yields were analyzed using regression analysis in order to determine water yield change variations over a given period of time. A second water yield analysis was conducted utilizing a computerized hydrologic model.

The analysis of land use and vegetative cover showed that the amount of urban, agricultural and open lands with low evapotranspiration

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[6] A dissertation presented by H. Ross Pywell III for the degree of Doctor of Philosophy, Graduate School of the University of Massachusetts, August 1977.

vegetation decreased from twenty-seven percent of the watershed in 1914 to four percent in 1971, while the area forested with large dense trees increased from a fraction of one percent to seventy percent during the same period.

Dr. Pywell contended that a 6.72 inch decline in annual water yield into the Swift River took place over the 58 year study period with the greatest decrease coming during the growing seasons when evapotranspiration is at its highest level.

Pywell believes that if the statistics developed in the study are valid, returning the 97,500 acres of watershed lands above the reservoir to there 1914 status, will result in an increased annual yield of 18 billion gallons of water.

Based on a per capita daily consumption of 176.6 gallons, an increased annual yield of 18 billion gallons of water could meet the annual water needs of 279,247 citizens.

VI. PRESENT STATUS OF WATERSHED MANAGEMENT

A. Executive Office of Environmental Affairs

The Executive Office of Environmental Affairs (EOEA) has the power to develop policies, plans and programs for carrying out the duties related to air, water and land resources including the proper management of public and private forest lands in order to preserve, among other things, their hydrological significance. It is specifically empowered to advise, assist and cooperate with departments, agencies, commissions, etc. involved in matters under their control as well as to promote the development of sound environmental education programs.[7]

Within EOEA, those agencies which have specific statutory powers in water related matters, include the following: the Metropolitan District Commission; the Bureau of Forest Development, within the Division of Forests and Parks; and the Division of Water Resources under the Water Resources Commission within the Department of Enviromental Management. An analysis follows of what role each of these agencies is actually performing in the way of watershed management on state or MDC land and what assistance they are providing to watershed owning municipalities.

B. Metropolitan District Commission Watershed Management Program

The Metropolitan District Commission Water Division has operated a limited integrated watershed management program on its Quabbin Reservoir, Ware River and Wachusett Reservoir watersheds since 1962. The program, developed as a result of the Cadwell Creek experiment. Its

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[7] M.G.L.A., Ch. 21A, s. 2

purpose was to increase water supplies, generate revenue and improve the overall recreational and wildlife opportunities on its lands.

Over 24,000 acres of the potentially manageable 73,000 acres of MDC land has been treated over the past fifteen years. MDC's plan is to annually cut and clear an additional 2500 acres with the 5000 plus acre Sudbury Watershed to be included at some future time.

Table 4 prepared by MDC indicates the manageable acreage in each of the watershed areas.

TABLE 4

MDC Watershed Acreage

	Total Watershed (Acres)	MDC Land (Acres)	Non-Manageable (Acres)	Total Management (Acres)
Quabbin	94,040 *	56,000	10,000	46,000
Ware	62,720	20,000	3,000	17,000
Wachusett	68,921 **	5,800	800	5,000
Totals	225,681	81,800	13,800	68,000 ***

* Does not include 25,000 acres of Reservoir.
** Does not include 4,200 acres of Reservoir.
*** The use of the Sudbury Reservoir is presently under study. The lands around this reservoir will also be managed when a program for its use is completed (5,000 acres).

MDC estimates it has achieved an additional water yield of 1 billion gallons annually, from the 24,000 acres already under a watershed management program.

In addition to increasing water supplies, the MDC Chief Forester estimates that the intensive watershed management program he administers has the potential of producing a total revenue for MDC over the next five years in excess of $2.5 million while costing MDC less than $50,000 for salaries and overhead.

The revenue is projected from the direct and indirect sale of stumpage and the dollar value added due to increased water yields.

HPAB believes that it will be difficult for the Chief Forester and his staff of four, to meet the projections of annual timber sales of 4 million board feet, 14,000 cords of wood, and 75 acres of red pine clearing, while maintaining an increasing amount of previously managed acreage. The importance of continued maintenance is evidenced by the drop off in yields at Cadwell Creek when the previously cleared riparian zone became vegetation covered in the fourth year of the experiment.

The management program in operation on the MDC watersheds has proven to be economically sound. But more importantly, it has the potential of increasing water yields by billions of gallons annually over the next twenty years. To achieve this, MDC must expand its efforts by hiring an additional forestry team. This would increase MDC's present program of 2,500 acres per year to 5,000 acres annually. Furthermore, this would excellerate the completion of the management cycle from 20 years to 10 years.

C. Division of Forests & Parks - Bureau of Forest Development

1. State Lands

The Bureau of Forest Development has the responsibility for the rehabilitation and protection of forest lands for the purpose of conserving water, preventing floods and soil erosion, while improving the conditions for wildlife and recreation.[8]

A large percentage of lands under the care and control of the Division of Forests and Parks are watershed lands, but there is no statutory reference requiring the Bureau to either develop or implement an intensive watershed management program for these lands. Bureau personnel are fully aware of the increased water yield potential which can be achieved through intensive management, however the primary goal of the Division is the advancement of recreational interests and increasing revenue through the sale of timber and cord wood. Revenue generated from these sales totalled $675,825.00 in fiscal year 1982.

Despite concern over water supply shortages, no coordinated policy or steps have been initiated by EOEA to consolidate the efforts of the Bureau with MDC on the estimated 24,000 acres of state forest and park land which abut MDC watershed lands. The intensive management of the 24,000 acres has an increased water yield potential for the MDC of at least one billion gallons annually.

2. Municipal Watershed Lands

The Bureau of Forest Development has thirteen service foresters located throughout the state. In addition to providing advice and assistance to private landowners, the service foresters are available on a request basis to provide technical expertise to municipal watershed managers. Potential

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8 M.G.L.A., Ch. 132, s. 40

for increased water yields, improved wildlife habitat and revenue production from timber sales are areas where service forester advice to municipalities can prove valuable. Unfortunately, the majority of municipal watershed managers are unaware that this service is available from the state.

D. Water Resources Commission

The Division of Water Resources is under the direct control of the Water Resources Commission. It is an eleven member board consisting of six state agency heads and five members of the general public.

The Commission has the statutory responsibility to meet and consult on matters concerning watersheds, water systems, storage basins, underground and surface water supplies. Further, it studies the needs, supplies and resources of the Commonwealth with respect to water conservation and flood prevention.

Primarily, the Commission has involved itself in capital improvement projects, processing applications for assistance under the Federal Watershed Protection and Flood Prevention Act, and coordinating the administration of the State's contribution to the cooperative survey program of the United States Geological Survey.

A. University of Massachusetts - Department of Forestry and Wildlife Management

In 1977, the Berkshire County Cooperative Extension Service in conjunction with the University of Massachusetts prepared a written watershed management plan for Berkshire and Hampden County communities.

Each community was assessed a minimal amount for their watershed management study plan, ranging from $175 to $477. The requirement for some local funding was intended to stimulate town interest, and to encourage control and implementation. The study costs, although sounding nominal, amounted in one case to one-half of a town's water works consulting budget.

Students from the University, working under the supervision of the County Extension Forester and the University staff have conducted studies for ten communities and have scheduled 8 additional studies for the current year. Four of the ten communities have harvested timber with a total income of $266,110. Table 5 shows the current status of the ten management studies.

TABLE 5

Forest Management Study Data

Municipality	Acreage	Study Date	(MBF) Annual Volume	Projected Annual Income	Study Cost	Income to Date
Adams	347	1981	83	$ 6,610	$ 175	*
Chesire	529	1981	130	10,400	200	*
Dalton	1,854	1977	400	27,000	400	51,547
Great Barrington	320	1981	-	-	300	*
Lenox	436	1979	171	11,218	430	16,896
North Adams	2,465	1979	877	65,751	400	191,099
Stockbridge	672	1980	479	26,678	477	*
Williamstown	528	1980	161	8,034	200	6,568
Chester	774	1981	243	9,386	399	*
Springfield	1,434	1981	502	30,156	209	*
Totals	9,359	-	3,046	$ 195,233	$ 3,190	$ 266,110

MBF - Thousand Board Feet

* No timber harvesting to date.

The total cost for the ten watershed management studies on 9,359 acres was $3,190. The four communities that have harvested timber have earned total revenues of $266,110, as a result of the management studies which cost $1,430.

Equally as important as the initial revenue producing potential of watershed management, is the enhanced future earning power of the forest due to increased growth.

B. Watershed Management Survey Data

Based on information provided by the State Water Resources Commission there are approximately 95 communities in the state which have active surface reservoir watersheds located within their geographic boundaries. It is estimated by the Bureau of Forest Development, from information gathered in a sample telephone survey of municipalities, that the land mass surrounding all surface reservoirs totals 150,000 acres. However, 58,000 acres are located outside of the communities geographical boundaries. In addition, the Metropolitan District Commission owns 81,800 acres of watershed land in the Quabbin Reservoir, Ware River, and Wachusett Reservoir areas. In total, almost 5% of the state's land mass or 362 square miles is owned by the Metropolitan District Commission or municipalities, as watershed land for drinking water systems. The extensiveness of government owned watershed land is further expanded by the inclusion of an estimated 24,000 acres of state owned land which are contiguous to MDC watershed lands. An example of this type of land would be the 1,900 acre Mt Wachusett Reservation in Princeton and Westminster, the runoff from which feeds into the MDC's Wachusett Reservoir.

Having a rough approximation of the total extent of municipally owned watershed land, the federally funded Forest Resources Planning Program, (Bureau of Forest Development) Subcommittee on Municipal Land, conducted a water supply lands survey in 1981. Officials responsible for water management in seventy-nine municipalities were contacted by telephone and asked to respond to a series of questions dealing with watershed land. Fifty-one of the seventy-nine sampled municipalities responded that they did in fact own watershed land within their own geographic boundaries or within surrounding communities. Twenty-six of the fifty-one respondents

have active or inactive surface reservoirs with watersheds ranging in size from 150 to 14,000 acres.

Table 6 which follows categorizes the responses which primarily deal with the intensive management of watershed lands, for the twenty-six respondents with sizeable land holdings that would benefit both financially and in terms of water yield from an intensive watershed management program. The twenty-six municipalities reported owning in excess of 50,000 acres of watershed land or one-third of the estimated statewide total.

The survey, which sampled 22% of the state's municipalities, is of sufficient size to draw the following statewide conclusions.

- Only 25 to 30% of the municipalities have a written plan for managing their reservoir watershed land.
- Over 70% of the municipalities have no written plan for managing their watershed land.
- Only 25 to 30% of the municipalities have full time positions allocated to managing watershed land, with 20% of those having no specialized education.
- At least 40 to 50% of the municipalities are not carrying out any type of watershed management program at this time.
- Over 50% of the municipalities claim they are actively managing their land, however, this is questionable due to the lack of a management plan, full time management personnel or specially educated full time personnel.
- Only 25% to 30% of the municipalities are carrying out any type of intensive management of their lands.
- Only 15% of the watershed owning municipalities in the state are allowing commercial timber harvesting.

- At least 15% of the municipalities admit they don't allow timber harvesting because of a lack of expertise.
- At least 40% of the municipalities demonstrate their lack of knowledge about watershed management by not allowing timber harvesting because of the fear of butchering the land or the belief it is an inappropriate activity.
- At least 60% of the municipalities with reservoir watersheds are practicing the traditional approach of total forest protection.
- At least 45% of the municipalities, with watershed land are unaware of the assistance available to them through the Bureau of Forest Development service forester program.
- Only 6% of the municipalities in the state have utilized the expertise of the service forester program.
- Timber harvesting is taking place on less than 10,000 acres of the 50,363 identified in the sample.

C. Conclusion

Intensive watershed management in the form of timber harvesting and vegetation control is not being practiced on 85% of the municipally owned watershed land in the state because of a lack of knowledge and expertise.

The uncontrolled basal area growth of trees on over 100,000 acres of municipal reservoir land is resulting in a decreased water yield into our reservoirs, amounting to billions of gallons annually.

TABLE 6

MUNICIPAL WATER SUPPLY LANDS SAMPLE 1981 TELEPHONE SURVEY OF 79 COMMUNITIES*

2,500	2,500 - 10,000	10,000 - 25,000	25,000 - 50,000	50,000 - 100,000	100,000 +	State Totals	Population Category
20	23	18	11	4	3	79	Total Number of Towns
25,644	136,044	274,953	385,541	279,062	964,260	2,065,493	Total Population (Of All Towns)
3	19	16	8	3	1	51	Have Watershed Land
2	1	0	0	1	0	4	Plan to Acquire Watershed Land in Next 5 Years
831	4,301	3,097	7,457	5,154	485	21,322	Acres in Town
0	130	1,017	7,961	880	2,000	11,988	Acres Outside Town
200	274	845	3,664	580	1,300	6,863	Acres in Water
0	3	0	2	1	1	7	Gave a Written Management Plan
3	16	16	6	2	1	44	Don't Have a Management Plan But Hope to in Next 5 Years
0	4	0	2	1	2	9	Gave Full Time Positions Allocated to Managing Land
0	0	0	1	1	2	4	Have Full Time People With Specialized Education
2	9	9	5	2	2	28	Are Currently Actively Managing These Lands
0	1	1	2	2	2	8	Are Managing Lands Intensively
3	8	8	3	0	0	22	Are Managing Lands Extensively
0	2	1	1	0	1	5	Allow Timber Harvesting on These Lands
0	1	1	2	1	0	5	Don't Allow Timber Harvesting Lack of Technical Expertise
2	6	7	1	2	0	18	Don't Allow Timber Harvesting Not Enough Trees
0	3	4	1	0	0	8	Don't Allow Timber Harvesting Fear of Butchering Trees
0	2	0	0	0	0	2	Don't Allow Timber Harvesting Fear of Community Opposition
0	1	0	0	0	0	1	Don't Allow Timber Harvesting Lack Knowledge
0	3	4	1	0	0	8	Don't Allow Timber Harvesting Not Appropriate Activity
1	8	6	3	1	1	20	Don't Allow Timber Harvesting Other
0	5	5	2	1	0	13	Permit Unqualified Recreation
2	13	8	4	2	1	30	Don't Permit Unqualified Recreation
2	7	3	5	2	0	19	Have Heard of Service Foresters
0	1	0	3	1	0	5	Have Used Service Foresters

Source: Commonwealth of Mass. Bureau of Forest Development Forest Resources Planning Project

GLOSSARY OF TERMS

GLOSSARY OF TERMS

Basal area - Total square footage of timber in a prescribed area, measured by estimating the total diameter of the trees at breast height (D.B.H.)

Example: Optimum basal area of a one acre pine plantation equals 90 sq. ft.

D.B.H. - Diameter breast height — Unit of measurement for timber.

Evapotranspiration - Water withdrawn from the soil by evaporation and from vegetation by transpiration. In both cases it is transmitted into the atmosphere in vapor form.

Hydrologic cycle - The process by which water is transferred to the atmosphere, in vapor form, through evaporation and evapotranspiration from the soil, vegetation and or bodies of water. It falls again some distance away in the form of precipitation which is either intercepted by vegetation and evaporates again, runs off the soil into reservoirs, ponds, etc. in the form of stream or river flow, or is absorbed into the ground and becomes groundwater.

Hydrology - The science dealing with the occurrence, circulation, distribution and properties of the water of the earth.

Interception - Precipitation usually in the form of snow which is trapped in the crowns of trees and evaporates or is eventually blown outside of the watershed area.

Precipitation - Moisture in any form; rain, snow, mist, etc. which reaches the earth's surface as part of the hydrologic cycle.

Riparian zone - The area of land immediately adjacent to a watercourse, e.g. flowing stream or river.

Safe yield - The dependable yield of water from a reservoir which will leave a sufficient capacity over a long term period to handle emergencies, droughts or equipment malfunctions.

Streamflow - The measurable volume of water in a river or stream passing a point over a period of time, usually described in cubic feet per second.

Watershed - A geographic area forming a drainage basin, the slope of which allows a raindrop, if not intercepted, evaporated or transpired, to make its way above or below ground into a stream or river and in the case of a manmade impoundment flow past a dam site.

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